ARS SPECIAL REPORT

GRANULAR INSECTICIDES
research developments and uses

ARS 22-78

Growth Through Agricultural Progress

March 1962

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

FOREWORD

More and more farmers today are turning to granular insecticides to protect their crops against certain insect pests. Federally controlled eradication and control programs against the imported fire ant and other soil-inhabiting insects now rely almost exclusively on granular formulations. The fact that insecticides in granular form, under certain conditions, are more effective than insecticides in spray or dust form is one of the reasons that dictate these choices.

To get the maximum benefit possible from each ounce of insecticide used in the eradication and control programs, scientists of the Agricultural Research Service continually investigate the physical and chemical makeup of granular formulations. These investigations have established the fact that standardization of granular insecticides for certain specific uses saves time and money. Other facts about granular insecticides and their use to protect fruit, vegetable, and forage crops, animals and man come from other ARS research and State research in many parts of the United States.

This report delineates the results of this research. It shows the progress that ARS scientists have made in establishing specifications for an acceptable granule--progress that may ultimately set a pattern for industry.

This report is for agricultural leaders and others who may be called upon to answer questions about the use and formulation of granular insecticides.

Information in this report was provided by the Entomology Research Division, the Agricultural Engineering Research Division, and the Plant Pest Control Division of the Agricultural Research Service.

GRANULAR INSECTICIDES
Research Developments and Uses

The basic granules of granular insecticide formulations are small, individually distinct particles of clay or other substances called the carrier.

The carrier is impregnated with the insecticide. When applied, the granules disintegrate and release the insecticide. The rate of disintegration and the rate at which the insecticide is released depend on the nature of the carrier and other factors. Solvents are usually needed to dissolve the insecticide before it is sprayed on the carrier. Other chemicals may be needed to deactivate the carrier so it will not contribute catalytically to the premature decomposition of the insecticide.

Interest in granular insecticides apparently received its initial impetus in 1950 when entomologists at the Arkansas Experiment Station used them successfully to control mosquito larvae in rice fields. Since 1950, the use of granular insecticides has grown rapidly and has contributed materially to insect control in the United States. The use of insecticides in granular form is a promising technique and for this reason scientists of the Agricultural Research Service continue to study granular insecticide formulations--many of their characteristics, peculiarities, and potentialities have not as yet been established or explored.

SOME IMMEDIATE, PRACTICAL CONSIDERATIONS

Because chemical manufacturers produce to meet customer demands, granular formulations currently available differ greatly in physical and chemical makeup. There are large numbers of granular sizes available, large ranges of sizes may exist within a given formulation, and one formulation necessarily may contain as little as 1 percent toxicant while another may contain as much as 50 percent. Different manufacturers may also use different carriers and this contributes to this wide variance. Equal volumes of different carriers, for example, containing equal percentages of the same toxicant on granules of approximately the same size, may still spread differently because one carrier may weigh more per unit volume than another. Certain techniques used in manufacturing granules contribute further to this variation.

Although ARS scientists and other authorities concede that standardization of granule size, percent toxicant, and physical makeup of granular formulations would greatly aid field use of any given insecticide, they also concede that the question of universal standardization is complicated. Industry and other interested groups are working on the standardization problem, but have not, as yet defined the limits of practicality. In the imported fire ant eradication program, where a specific use was involved, strict insistence that the granules used meet certain specifications has

produced economies with no loss in effectiveness--the strict insistence contributed materially to a decrease in dosage from 2 pounds of actual toxicant per acre to two applications of one-quarter pound each per acre. This achievement seems to indicate that further research will ultimately define the conditions that will ultimately lead to some degree of standardization in the manufacture and use of granular insecticides.

SOME COMPARISONS

In 1948-50, the entomologists at the Arkansas Experiment Station found that DDT, dieldrin, and other insecticidal sprays did not control mosquito larvae effectively in rice fields--the spray impinged on foliage and failed to reach the water where the larvae were. When the entomologists used the same insecticides in granular form, however, success was eventually achieved. The granules used penetrated the foliage and fell into the water. Once in the water, they disintegrated and released the toxicant. Only three live larvae were later collected in the 12 granular-treated test plots sampled; whereas samples collected in two untreated plots produced 78 and 61 larvae.

In addition to their ability to penetrate foliage and reach the spot where they will do the most good, granules drift less than sprays or dusts because the individual granule is usually much heavier than discrete drops of spray or particles of dusts. This characteristic is a primary advantage in almost any pest-control effort. It means that granules can be applied with greater accuracy from airplanes and under conditions of greater air movement than sprays or dusts. Less drift also means that sensitive crops adjacent to the scene of operation are far less likely to be injured.

ARS scientists further found that some granules, as they fall, contact crop foliage only momentarily before reaching the soil. This slight contact harms the foliage very little so that insecticides that might be injurious to crops in spray form may, under certain conditions, be used in granular form with comparative safety.

Because of the momentary-contact and less-drift characteristics, granular-treated crops usually exhibit less harmful residue when harvested or utilized than spray- or dust-treated crops.

Granules can usually be used as they come from the supplier. Pumping, hauling, storing, or measuring water is not necessary. The troublesome problems of corrosion, pipe and nozzle clogging and cleaning, boom repair, or maintaining adequate pressure are more or less eliminated. Agitation in hoppers is not needed and may actually be a detriment because it would crush the granules.

But the bulkiness and other characteristics of granular formulations necessitate more and drier storage than concentrated liquids need. Granules also come in bags and these have to be lifted and carried; liquids can be pumped. With some notable exceptions, granules are not effective for foliage applications.

PATTERNS OF USE

Granular insecticides were used in the successful Medfly eradication in Florida in 1957-58--to control larvae and pupae in the soil under

infested trees. (The use of bait-spray was the principal method.) Granular insecticides are presently being used against the imported fire ant and white-fringed beetles in the Southeast and against the Japanese beetle in other areas. Other less extensive but nonetheless significant uses for granular insecticides appear in Agriculture Handbook 120, "Insecticide Recommendations of the Entomology Research Division for the Control of Insects Attacking Crops and Livestock for 1961." This handbook is published by the Agricultural Research Service and the Federal Extension Service, U. S. Department of Agriculture. It is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., price 65 cents.

The examples that follow, which have been extracted from the handbook and other sources, illustrate the versatility and some of the other characteristics of granular insecticides.

Against the European Corn Borer and the Alfalfa Weevil

Granular insecticides are effective against the European corn borer. This is probably one of the most interesting and gratifying developments in the field of pesticides.

When applied over corn plants in the whorl stage, the granules adhere temporarily to the leaves and then roll slowly into the whorls and leaf axils. (Spray usually adheres permanently to the leaves.) The whorls and leaf axils are respectively the primary points where young first- and second-brood larvae initially feed. The granules also fall deeper into the whorl leaves than spray and remain effective longer near these primary points of feeding. Moreover, concentration of the insecticide at the leaf axils reduces the amount of residue that might be available to cattle feeding on the stover after harvest.

These and other facts relating to the use of granules for European corn borer control were brought out by ARS scientists in the North Central States and other locales with the active participation and cooperation of the respective State Experiment Stations.

The alfalfa weevil, one of the most important pests of alfalfa in the Eastern States, can be controlled by using heptachlor granules. Although larval feeding during April and May causes the greatest losses, adult oviposition and feeding in the fall on stems and petioles weaken plants. Heptachlor granules, applied in the fall before oviposition, reduce plant damage. Rates per acre, optimum time of application, and other directions and precautions to be followed and observed in the granular treatment will appear in the 1962 revision of Agriculture Handbook 120.

ARS-State entomologists in Virginia, Maryland, North Carolina, and other Eastern States, conducted the research that established the heptachlor granule recommendation. Seasonal history studies of the weevil suggested fall applications. Control measures in the spring usually necessitate multiple applications of malathion or methoxychlor and the control obtained is usually erratic because larvae hatch over an extended period of time. Fall treatment offers the added advantage of reducing residues.

Insects Affecting Man and Animals

ARS scientists at Orlando, Fla., developed an interesting variation of the granular-insecticide technique. They mixed granulated sugar and

wettable powder of malathion, Diazinon, and other insecticides. In laboratory tests, a concentration of 0.1 percent toxicant in the sugar gave 99 percent kill of house flies in 16 hours. Higher concentrations gave considerably faster kills. Practical tests in dairy barns and poultry houses heavily infested with flies reduced infestations at least 90 percent within 4 hours. Five applications per week of the granules containing 0.5 to 1 percent toxicant over a period of 2 to 3 weeks gave highly effective control in most of the dairy barns. Similar results were obtained in poultry houses by repeatedly applying sugar granules containing 1 percent toxicant.

The scientists sifted the poison granules on the floors and other locations where flies congregated. Since flies feed on individual grains of sugar, the sugar could be scattered sparsely (about 1 gram for each 20 square feet). A domestic animal or fowl would have very little chance of eating more than a minute quantity of the poisoned sugar. This type of granular insecticide is inexpensive and easily prepared. The cost of equipment and time for application are small. Instructions for preparing the granules appear in USDA Leaflet No. 390.

These granular insecticides with sugar as a carrier are now generally recommended in unscreened dairy barns and poultry houses, on garbage and trash piles, or other places where the use of spray or dust would be impractical or undesirable. For moist surfaces, which would dissolve the sugar prematurely, the insecticide, sugar, and other ingredients can be mixed with sand or coarsely ground cornmeal.

The ARS scientists at Orlando have also used granular insecticides in Florida, South Carolina, and other places to control salt-marsh sand flies, salt-marsh mosquitoes, and blackflies in slow-moving streams. In all these tests, the ARS scientists confirmed and extended the findings of the Arkansas Experiment Station. All the areas treated were covered with heavy, dense vegetation.

To Carry Systemics

Systemic insecticides are absorbed into the roots or other parts of a plant and translocated through the plant. They subsequently kill insects when the insects feed on the plants.

In southern California, ARS scientists controlled the two-spotted spider mite on lima beans for 2 to 3 months by applying granular systemic insecticides in the seed furrow at planting time. Coating seeds with phorate before planting was much more phytotoxic than granule applications. During one year, stands treated with granules were generally better than those sprayed. During the following year, significant reductions in stand were apparent only from soil applications of liquid phorate. The use of systemics in any form generally increased crop yields and little or no residue of the insecticide was found in the dry beans.

Since the western flower thrips was present in the experimental fields, the scientists evaluated the treatments on this insect also, although it is not an important pest of lima beans. Thrips counts made at five different times during 1 year showed good to excellent results with liquid and granule applications of phorate; fair with phorate seed coatings, and from fair to poor with other insecticides. Counts made at three other times during the same year and averaged for all insecticides showed

no significant difference between liquid and granule applications in the soil. During the following year, foliage sprays were better than granules in the soil and the granules in the soil were better than liquids in the soil.

Also, in southern California, control of mites and aphids on strawberries, and aphids on turnips is often needed during the long harvest season. In 1956, ARS scientists ran preliminary tests to see if these pests could be controlled by early applications of systemic insecticides, some of which were applied in granular form. Results showed that sprays in the furrows near the strawberry plants gave excellent control of mites and aphids for 2 months and the control was just as good as spray on the foliage. Applications of the granular material in the furrows near the plants were less effective than sprays in the furrows and also less effective than spray on foliage. On turnips, however, granular applications in the furrows near the plants were better or just as good as spray applied in the furrows near the plants or on the foliage.

In Oregon, ARS scientists successfully controlled aphids on lilies all season by applying granular, systemic insecticides after the bulbs were set out but before they were covered. The insecticides tested gave equally good results when mixed with the soil in the bottom of the furrow before the bulbs were set. But this practice is hazardous when planters set bulbs by hand because of the possibility of contacting the toxic insecticides. Soaking bulbs in an emulsion of insecticides was not as effective as putting the insecticides in the soil.

Against the Plum Curculio and Other Pests

The plum curculio is a common and serious pest of peaches, plums, cherries, and apples in States east of the Rocky Mountains. The adult feeds on and lays eggs in the fruit. The larvae feed in the fruit until full-grown, then leave the fruit and burrow into the soil to pupate and complete development to the adult stage.

Soil applications of granular insecticides have proved to be effective in control of this pest. In March 1957, ARS scientists treated the soil under 441 Regular Elberta peach trees near Reynolds, Ga., with granular aldrin, worked into the soil. No insecticide was used on the trees during 1957 through 1960. Subsequent harvests showed that only 1.6 percent of the peaches from the soil-treated orchards were infested in 1957, 2.9 percent in 1958, 0.7 percent in 1959, and 3.5 percent in 1960. Other experiments similarly proved the effectiveness of this type of treatment. In one instance, peaches from an untreated orchard, separated by a wooded area from a soil-treated orchard, were completely ruined by the plum curculio.

Similarly, insecticides applied in granular form and worked thoroughly into the soil have proved to be as effective as dusts and sprays in controlling the southern potato wireworm in coastal South Carolina.

THE MAKEUP OF ACCEPTABLE GRANULES

While work toward standardization of granular insecticides is in the discussion stage at this time, the experience gained by ARS scientists in using granular insecticides against the white-fringed beetle, the Japanese beetle, the Mediterranean fruit fly, the imported fire ant and other pests

has resulted in the gradual development of product-quality standards, or specifications, for four granular insecticides. At the present time, the specifications have attained the status of Interim Federal Specifications. As experience is accumulated and the specifications further revised and refined, they may be adopted as Federal Specifications. If they reach this last stage, then their use is mandatory for purchases made by Federal agencies. Adoption of the specifications by the Government may set a pattern for the industry; in fact, industrial representatives participate in the development of the specifications.

The four Interim Federal Specifications for granular insecticides that have been issued are: O-I-00528a for heptachlor, O-I-00512 for aldrin, O-I-00525 for dieldrin, and O-I-00516 for chlordane. Single copies of these specifications may be obtained through regional offices of the General Services Administration, an agency of the U. S. Government, in Boston, New York, Atlanta, Chicago, Kansas City, Mo., Dallas, Denver, San Francisco, Los Angeles, Auburn, Wash., and Washington, D. C.

From the specifications and other sources an acceptable granule for use against soil-inhabiting insects can be tentatively defined and this granule can be modified for other uses. In physical form, acceptable granular formulations are essentially dry, granular aggregates. They are free of excessive dustiness. They break down with reasonable ease under weathering into subaggregates and ultimate particles to facilitate the further distribution of the toxicant.

Particle-Size Characteristics

The particles of an ideal granular formulation would all be the same size. This ideal at this time, however, is impractical because manufacturing costs would be too high. Consequently, each ARS specification defines a range of acceptable particle sizes. Formerly this range extended from 1/4 to 1 millimeter (a millimeter is approximately 1/25 inch): present tendency is to raise the bottom of the range a little--to 0.42 millimeter. Reasonable but specific tolerances are stipulated for both ends of the range. Compared with familiar household commodities, a reasonably ideal granular formulation would have particles slightly coarser than table salt and granulated sugar, but smaller than celery seed. At least 98 percent by weight should pass through a U. S. No. 18 sieve, but not more than 5 percent through the specified bottom sieve, either U. S. No. 40 or 60. To establish the formulation's ultimate capacity to breakdown under weathering, at least 75 percent by weight should pass a U. S. No. 60 sieve in the ARS water-tumbling test, which is an integral part of the ARS specifications.

Sieve sizes that define a range of sizes are usually written as 18/40. This particular example means that the sieves have, respectively, 18 and 40 openings per linear inch. The more openings per linear inch, the finer the sieve mesh, and the finer the particles passing through the sieve. Other ranges in demand today include 15/30, 16/30, 18/35, 20/35, 20/40, 24/48, and 30/60.

At Ankeny, Iowa, one ARS experiment showed no difference in European corn borer control because of granular size, but in another significantly better control was obtained with 30/60 granules than with larger ones. From field experience against the imported fire ant and other pests, more uniform distribution and results were obtained with 18/40 mesh material than with finer materials such as 30/60.

Whenever granular sizes of formulations are discussed, the size designation should be the size of the finished product--not merely that of the granular carrier alone.

Carriers

The carrier designated in the ARS specifications is attapulgite, a form of clay. The specifications further designate that the attapulgite must be the AA RVM (RVM for regular volatile matter) type. AA means that the attapulgite is extruded and RVM means that it is uncalcined.

Extruding means that in the manufacturing process, the attapulgite is moistened and then forced (extruded) through small openings. This process disrupts the orientation of the microscopic particles of the attapulgite and makes it more absorbent than if it were unextruded. Uncalcined means that the attapulgite is not heated, or heated rather mildly. While true calcining (heating the product to drive out the uncombined and some of the combined water) also increases the carrier's absorbency, it inhibits the carrier's ability to release the toxicant. Unextruded calcined attapulgite is designated A LVM (LVM for low volatile matter).

In 1950, the Arkansas entomologists initially used a type of fuller's earth as the carrier. They found that the fuller's earth granules penetrated the foliage in the rice fields and fell into the water, but they failed to break down and release the toxicant. They remained hard and firm even after many days of soaking. When the entomologists used bentonite as the carrier, however, the granules disintegrated rapidly in the water and released the toxicant. The use of bentonite as a carrier when insecticides are dispersed in water may therefore be indicated. Attapulgite's and bentonite's superiority over vermiculite as a carrier was indicated in Iowa in 1958. While the rate of toxicant was held constant for each particle level, the Iowa results showed that significantly fewer European corn borer larvae were recovered from plots treated with attapulgite and bentonite than in those treated with vermiculite.

Other Iowa results showed that AA RVM attapulgite, tobacco-base, and bentonite as carriers were superior to perlite, celite, vermiculite and AA LVM attapulgite. Perlite and vermiculite were apparently undesirable because they weigh less per unit volume than some of the other carriers and because they do not hold the toxicant as well.

Solvents

The usual practice in manufacturing granular formulations is to impregnate sized attapulgite or other porous solids with a solution of the insecticide. Sometimes the active ingredient can be rendered sufficiently fluid by heat to make possible the omission of a solvent.

ARS has made considerable advances in the specifications for solvents. At first the descriptions were vague, saying little more than that the solvent should be a nonphytotoxic hydrocarbon and that the finished formulation should not be flammable.

ARS specifications today, however, place definite limits on the solvent's physical properties, such as initial, median, and final boiling

points, flash point, specific gravity, and viscosity. ARS deliberately selected these limits to admit several well-known brands and grades that have given satisfactory service and to eliminate almost anything else that is not their equivalent. The amount of solvent is sometimes fixed as high as 20 percent of the finished mixture, though sometimes much less is prescribed. A convenient, quick test to check on a solvent's phytotoxicity is not yet available.

At Orlando, Fla., ARS scientists, studying release of some organic phosphorus insecticides into water from granular formulations, saturated the carriers with acetone solutions of the insecticides and then evaporated the acetone with an air stream. Acetone, however, swells bentonite granules so benzene was used instead. In tests against sand fly larvae, ARS scientists prepared BHC granules by spraying melted BHC on bentonite while the granules tumbled in a cement mixer.

Seeking to improve the kill by heptachlor granules in the imported fire ant program, ARS scientists used experimental granules formulated with various solvents. They tested the new formulations against granules formulated with a heavy aromatic naphtha, one of the standard solvents. Eight-week counts on a series of 1-acre plots showed all formulations made good kills, but that granules containing a lube oil, or a certain resin, or an alkylated polystyrene made better kills than the standard or some of the other solvents used. These preliminary tests were so promising that a 40-acre plot has been set up for further tests of the alkylated polystyrene. Five different viscosities have been obtained for further small-plot testing.

The toxicant may partitionally separate from the solvent on the soil's surface and prematurely evaporate. ARS scientists engaged in the imported fire ant program studied this phenomenon and added nonvolatile solids to experimental formulations. The solids were a rosin and a chlorinated terphenyl. Formulation of the solids and heptachlor with the attapulgite was carried out in the usual manner except that a co-solvent methylene chloride was used. After formulation, the methylene chloride was allowed to evaporate. Results showed that these solid-additive formulations retained nearly twice as much toxicant as formulations with the standard heavy aromatic naphtha.

Chemical Stability

Any mineral carrier may contain minute quantities of copper, iron, or other heavy metals, or acid sites on the mineral surfaces, that could contribute catalytically to premature decomposition of the insecticides. ARS specifications recognize this possibility and usually stipulate (a) both the carrier and the deactivator--a chemical to offset any catalytic action of the carrier, (b) a carrier known to be catalytically inactive, or (c) a stability test for determining acceptance. Any of these methods may be adopted with dieldrin and aldrin, but with certain other toxicants the stability-test plan is complicated and has not been worked out satisfactorily.

The ARS specifications stipulate that attapulgite destined for granular dieldrin must be deactivated with urea. Attapulgite for aldrin granules also requires urea; while attapulgite for chlordane and heptachlor granules requires a deactivator of a different type. Deactivators are usually added before the toxicant is sprayed on the granules, but in some of the 10- and 20-percent formulations, they may be added along with the toxicant.

Industry has long recognized this problem of chemical incompatibility between the ingredients of insecticidal dusts. Industry's present research in this problem is being extended to include granular formulations.

Homogeneity

In an ideal formulation, each granule would be up to grade and carry its full share of the toxicant. Commercial materials have been examined from time to time and it is usually found that all particle sizes have the same rate of toxicant impregnation.

The fundamental problem in approaching homogeneity in granular formulations is to avoid undue dustiness. An excessively dusty formulation would defeat the purposes for which granular pesticides are used (for example, to reduce drift) and it would seriously interfere with application flow rates.

The measure of dustiness commonly used is the percentage passing the 250-micron (U. S. No. 60) sieve in dry tests. This size of sieve is about the coarsest that is applicable to dust evaluation. In the imported fire ant and other eradication programs, hundreds of tons of material have been supplied to meet ARS specifications limiting the fine (under 250 micron) fraction to 5 percent.

Determining the degree of dustiness in a formulation has been difficult because of the unsatisfactory reproducibility of known methods. An ARS physicist, however, recently developed a turntable-sampling method that materially reduces this difficulty.

Variation of dustiness with storage also influences the homogeneity of a formulation and this variation is often unpredictable and sometimes erratic. Packaging and shipping may similarly influence homogeneity if the formulation is packaged before sufficient curing time has elapsed--premature packaging can result in delivery of a formulation that is still damp, or one that is dustier in the acceptance test than it would be after a reasonable storage period.

Drillability

Manufacturers of equipment for applying granular insecticides require formulations that are free flowing. But some formulations may be "wet" or oily. Even though not visibly "wet," such products are quite prone to cake or set up after packaging.

Formulations exhibiting this tendency are usually aged or cured before they are packaged. The finished product is simply stored in piles or in open drums and excess solvent is lost by volatility. The aging or curing also contributes to better distribution of the insecticide and solvent within the granules.

Conditioning of 20- and 25-percent granular heptachlor and other highly concentrated formulations eliminates the need for an aging period. After the impregnation, finely milled diatomaceous earth or other conditioning agent (3 to 5 percent by weight of completed batch) can be blended in for a few minutes. The finely divided conditioner coats the granules and

inhibits their tendency to stick together. The percent of free dust in the product is not increased significantly because the conditioner usually adheres firmly to the granules.

Other factors that influence the drillability of different granular insecticide formulations include their weight per unit of volume and the angle of repose they assume when in a hopper. Table 1 shows these physical properties for different formulations of DDT. Although the figures come from ARS work against the European corn borer in Iowa, they are apparently valid for other areas, and for insecticides other than DDT because the type of carrier used influences the physical properties of a formulation more than any other factor.

TABLE 1.--Physical properties of granular insecticides

Carrier	Formulation		Emptying[a] angle of repose	Volume[b] weight	Other properties
	Particle size	DDT			
		percent	*degrees*	*lbs./cu. ft.*	
Attapulgite RVM	15/30	$7\frac{1}{2}$	38	41.8	
	30/40	$7\frac{1}{2}$	38	41.4	
	30/60	$7\frac{1}{2}$	37	39.2	
Attapulgite LVM	15/30	$7\frac{1}{2}$	40	45.1	
	30/40	$7\frac{1}{2}$	40	41.3	
	30/60	$7\frac{1}{2}$	39	42.0	
Tobacco	15/30	10	42	21.4	Special extracted.
	20/40	10	42	18.6	Special extracted.
	30/60	10	43	18.6	Special extracted.
Attapulgite RVM	30/40	4	35	43.0	Adjunct added.
	30/40	4	37	42.2	
	30/60	4	39	42.3	
Tobacco	30/60	4	41	30.3	Sterilized.
	30/60	4	41	18.2	Special extracted.
Bentonite (sodium)	30/40	4	37	73.0	Hygroscopic and easily dispersible in water.
Perlite	20/40[c]	4	44	15.7	Heat expanded, hard particles resembling tiny bubbles of glass.
Celite	30/60	4	60	27.2	Calcined aggregate, similar to diatomite.
Vermiculite	20/60[c]	4	40	14.4	Heat expanded mica No. 4.

[a] Angle at which material will stand as determined by filling a box approximately 5 by 4 by 3 inches, removing one end, and measuring the angle of the material.
[b] Determined with a Boerner weight per bushel apparatus.
[c] Approximate.

EQUIPMENT FOR APPLYING GRANULAR INSECTICIDES

Granular insecticides can be applied conveniently by hand. In plum curculio orchard tests, the soil under the spread of 441 trees was treated by hand with 2-percent aldrin granules. Peach growers in Georgia have treated the soil under nearly 7,000 peach trees by means of tin cups in the hands of laborers; however, this type of application is not recommended when more than a few trees are involved.

The granular sugar house fly baits are usually applied by hand from cans or jars with perforations in the tops.

But the economical application of granular insecticides over large acreages naturally necessitates the use of power-driven spreaders. Conventional farm equipment--grass seeders, granular fertilizer distributors, and others--have been used for this purpose and more specific machines and attachments have been developed. An important part of ARS research is aimed at investigating these devices and developing better ones.

Some of the commercial devices now available for applying granular insecticides include universal mountings that attach to any planter, lister, or seeder, applicators that are said to have precision metering dials to control application rates accurately, and positive feeds and positive shut-offs to eliminate waste from leakage. A single unit applicator that applies only granular insecticides may cost about $58. A kit to convert this applicator for granular herbicides may cost about $18.00. A double applicator that applies both granular insecticides and herbicides may cost about $110.

Some Evaluations of Carriers and Ground Machines

ARS and State scientists at Ankeny, Iowa, evaluated five machines and seven types of granular carriers. They determined the angle of repose for all of the materials (see table 1) and found them to vary from 35 to 60 degrees. If the flow of material through any application equipment, therefore, depends on gravity, an angle of not less than 50 degrees from the vertical must be provided for all hopper sides, bottoms, and so forth to prevent bridging.

Also as shown in table 1, the volume weights of the carriers plus the insecticides vary from 14.4 to 73.0 pounds per cubic foot. Using these extremes as examples and assuming a fixed percentage formulation, the discharge per minute for vermiculite would be six times greater than for bentonite. To use the given carriers, therefore, application equipment should be adjustable enough to take care of this variation.

The ARS scientists further determined the rate of discharge in pounds per minute for the normal operating speeds of various metering mechanisms:

An auger-type fertilizer distributor and a fluted-feed grass seeder gave rates of discharge that varied directly with the speed of rotation of the metering mechanism.

A fluted-shaft granular distributor gave a rate of discharge that decreased slightly as the speed of rotation of the shaft increased.

Reciprocating-chain and a reciprocating-rope grass seeder showed discharge rates that increased slightly as the speed of reciprocation increased.

The auger-type or the fluted-feed type would be the best choice for ground-driven applicators if the speed of travel in the field cannot be controlled.

All of these mechanisms showed good speed discharge relationships when the speed was held constant. The physical breakdown of granules that were metered through the various machines was not serious.

Also in Iowa, however, earlier applications from a self-feeding power duster were ineffective. Tobacco-base formulations tended to bridge at the feeding openings and caused uneven flow. The agitator caused some breakdown of particles. Attapulgite granules packed in the hopper bottom and the packing was serious enough to break the agitator and the feed belt. Investigators at the South Carolina Experiment Station, Clemson, reported similar difficulties with tractor-driven rowcrop dusters, especially when hoppers were full. They suggested removing agitators. Several manufacturers are supplying adjustments for their dusters to accommodate granules.

In 1950, the Arkansas entomologists used an endgate seeder attached to a two-wheeled cart to apply dieldrin granules. The seeder was geared to the left wheel. When left turns were made the seeder operated at such low speeds that too little material was distributed.

In California, ARS scientists mounted granular applicators on bean planters and applied the granules as the beans were being planted. The applicators were traction-powered and metered the granules by the horizontal rotation of saw-tooth metal plates. The number of plates used varied the dosage. The granules dropped into the planter boot via flexible metal tubing. This method of applying granules was apparently effective because granular insecticides compared favorably in these experiments with sprays and seed coatings.

Spreading Granules by Airplane

The same problems encountered in ground applications of granular insecticides may occur when granules are distributed by airplane. The granules may not spread evenly and sometimes the swaths are too narrow to be economical. In the imported fire ant control work, a swath width of 200 feed with a 50-foot overlap is the up-to-now unattained ideal.

ARS scientists are attacking this problem on many fronts. In Oregon, an ARS engineer and an ARS entomologist have developed two efficient ways to disperse granular insecticides by airplane--from the wing and from a winglike attachment called an airfoil. The equipped, low-flying plane (a small, single-engine monoplane) harnesses air currents from the wing or the airfoil and from the propeller to distribute the granules. Swaths up to 45 feet wide are easily treated and concentration in the swath varies less than when granules are applied from a plane with conventional application equipment. A conveyor belt moves granules from a hopper in the fuselage to openings in the airfoil.

Other ARS scientists designed and installed a spreader on a 450-hp Stearman biplane.[1] In final tests, with the equipment calibrated for an application rate of 30 pounds per acre, a flight spacing of 40 feet produced the proper overlap of each swath to give an excellent over-all distribution of the material.

The success achieved with granular insecticides against the European corn borer encouraged ARS scientists to investigate the possibility of applying the granules by airplane[2] against the borer. Among other results, the ARS scientists found that distribution patterns for bentonite and attapulgite were similar--both have two-peaked configurations, that effective swath width tends to be greater with increased altitude, that crosswind displaces the distribution pattern of bentonite 2.3 feet per mile per hour for a 19- to 22-foot altitude range and attapulgite slightly more, and that the most successful applications occurred at an air speed of 80 miles per hour and an altitude of approximately 20 feet.

SOME FINAL CONSIDERATIONS

Granules are not magic. Overdoses may cause serious crop damage or residue hazards or both. Instructions on the supplier's label should always be followed and the insecticide should be used in accordance with existing regulations. Many effective procedures worked out for sprays and dusts apply also to granules.

Timing of Applications

Granular insecticides, like sprays and dusts, are usually applied to take advantage of the most vulnerable stage in the life cycle of an insect. The Arkansas entomologists, for example, timed their granular applications to reach the mosquito larvae and so did the ARS scientists in their applications against the sand fly, the salt marsh mosquito, and the blackfly. The European corn borer is controlled in the larval stage; the fire ant, the housefly, and the alfalfa weevil in the adult stage. Granules carrying systemics may be effective against insects in any stage in which they feed.

Calibrating

Calibrating distributing equipment is extremely important. It is usually necessary to calibrate for every new batch used and sometimes for every new sack because of the allowable range of sizes in a formulation and because some formulations may contain more dust than others. Some farmers find it convenient to affix paper bags at the dispersing points of applicators, run a measured course at a measured speed, and then weigh the granules collected. Calculations then show how many pounds of granules are being dispersed per acre. Other farmers calibrate their applicators in the field. They set their applicator to distribute less than the manufacturer recommends. They then measure out 1 pound of granules at a time and mark the level in 1-pound increments on the inside

---

[1] See ARS 81-5, "A Spreader of Granulated Materials for Installation on an Airplane," a publication available from the Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

[2] See ARS 42-25, "Characteristics of an Aircraft Distributor for Granular Materials," a publication available from the same source given in footnote 1.

of each hopper. The marks tell them how fast the granules feed down, and the applicator can then be gradually opened up to get the rate desired.

In the imported fire ant eradication program, some of the earlier formulations used varied by as much as 44 percent in specific gravity. Strict insistence that the formulations used meet the given specifications is expected to solve this problem, and to reduce the necessity for every-batch calibrations.

Some manufacturers furnish calibration charts with their applicators to set distribution rates that may vary from 8 ounces to 30 pounds of granules per acre.

Absolute precision in granular distribution is not necessary. ARS research shows that 4 granules per square inch are as effective as 25 per square inch. But every critical spot in an area must receive some treatment so relatively accurate calibration is a necessity.

Concluding Notes

The principal concern of the imported fire ant and other Federal-State, cooperative programs is not experimentation, but to down the pests as swiftly as possible and keep them down. Consequently, the specifications have to be confined to products readily producible, known to be trustworthy, and easily standardized. The narrow standards that have resulted are not meant to discourage future research on other types of carriers, other grain-size distributions, and other features in general than those accepted at present for control programs. Major problems still to be faced in development of granular insecticides include: (1) Control of dustiness, (2) evaluation of entirely new or insufficiently tested carriers, (3) further insurance against chemical instability and phytotoxicity, and (4) more refinement in defining adequate curing time.

Making granular insecticides more functional than at present by using granular fertilizer as the carrier needs further study. Some States prohibit insecticide-fertilizer mixtures; others require special tags. But thousands of tons are apparently being sold and many farmers make up their own mixtures.

Entomologists and other scientists are naturally enthusiastic about granular insecticides and look forward to tailored products from which the release-rate of the toxicant can be carefully controlled. The ARS specifications and the results of other ARS-State research are important steps toward that goal.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1962 O - 629806